MEMS Microphones at Draper

MEMS Air Acoustics Research

The Charles Stark Draper Laboratory

J. Bernstein

August 1999

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
24 AUG 1999	**N/A**	**-**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
MEMS Microphones at Draper	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Draper Laboratory**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

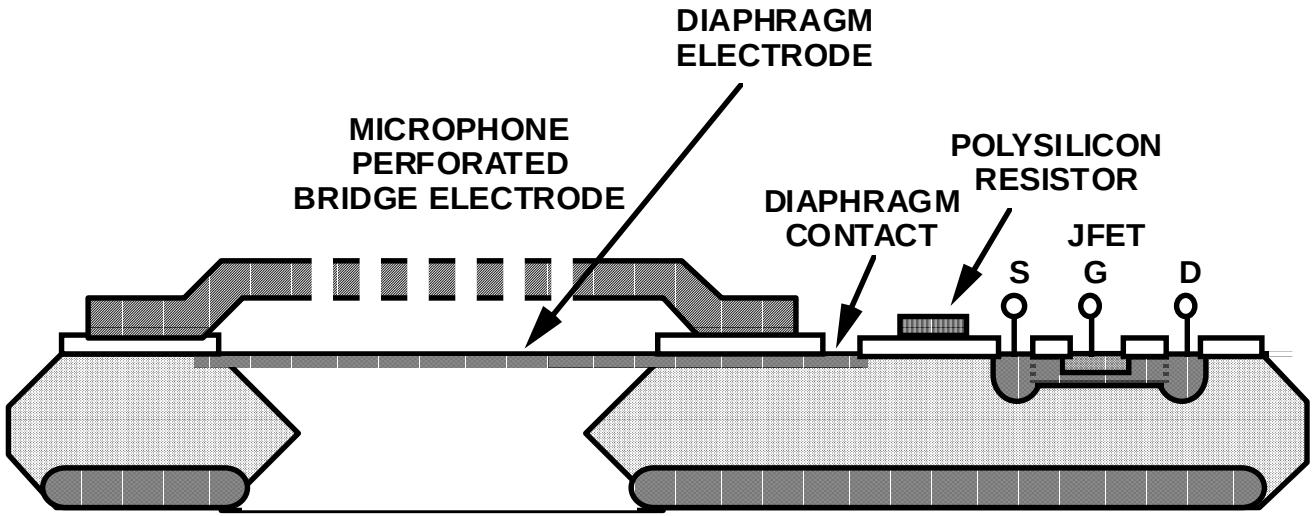
13. SUPPLEMENTARY NOTES
DARPA, Air-Coupled Acoustic Microsensors Workshop held on August 24 and 25, 1999 in Crystal City, VA., The original document contains color images.

14. ABSTRACT

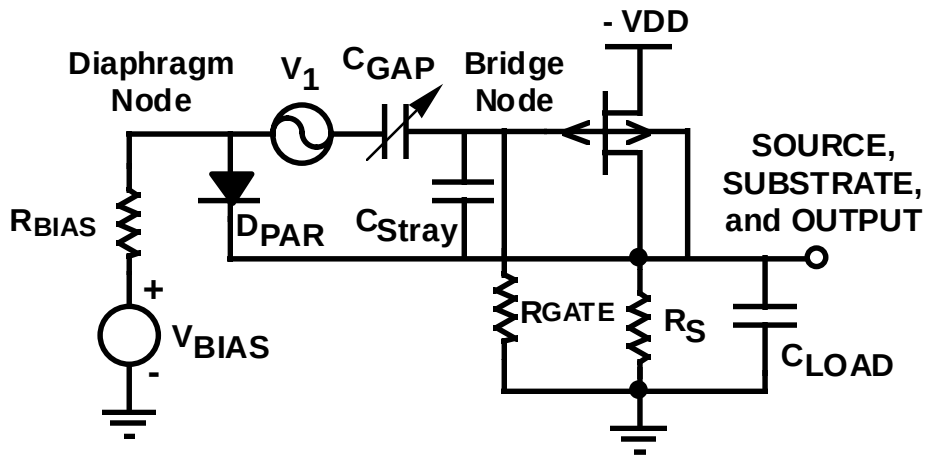
15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**UU**	**8**	

Condenser Microphone Cross-Section & Circuit Diagram

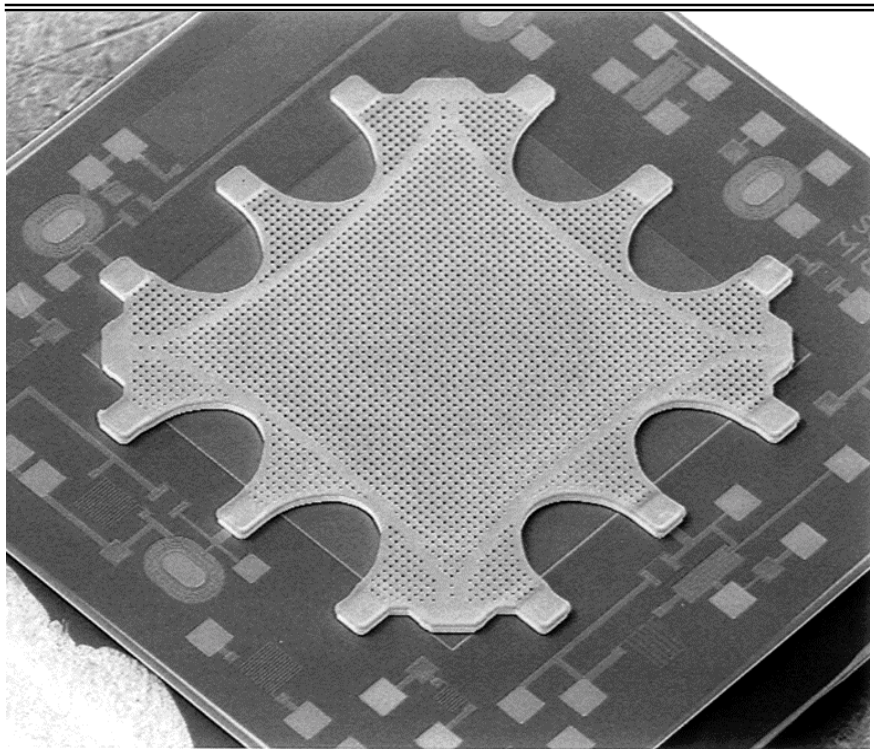


Cross-section of mike with on-chip JFET amplifier



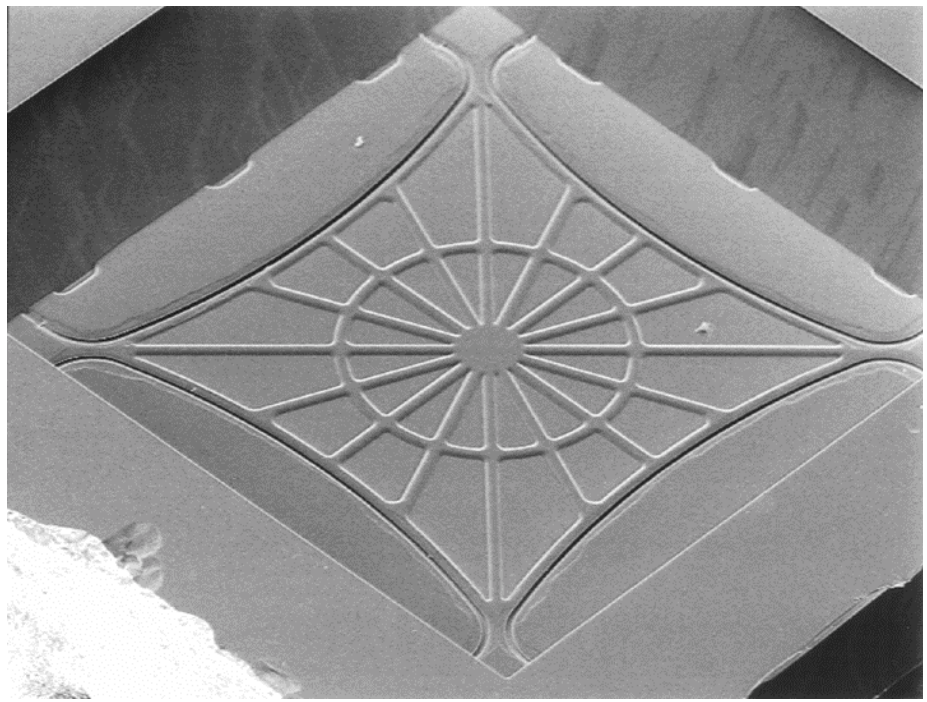
Circuit diagram with parasitics

Micromachined Microphone



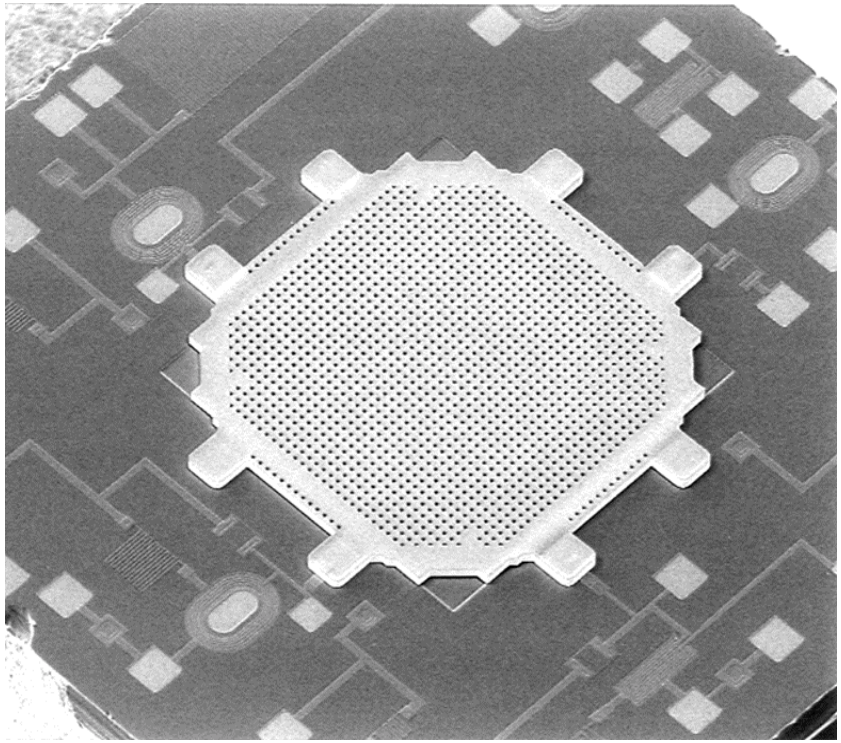
Front view:
Perforated bridge electrode
JFET buffer circuits

Back view:
Reinforced silicon diaphragm
Anisotropically etched through hole



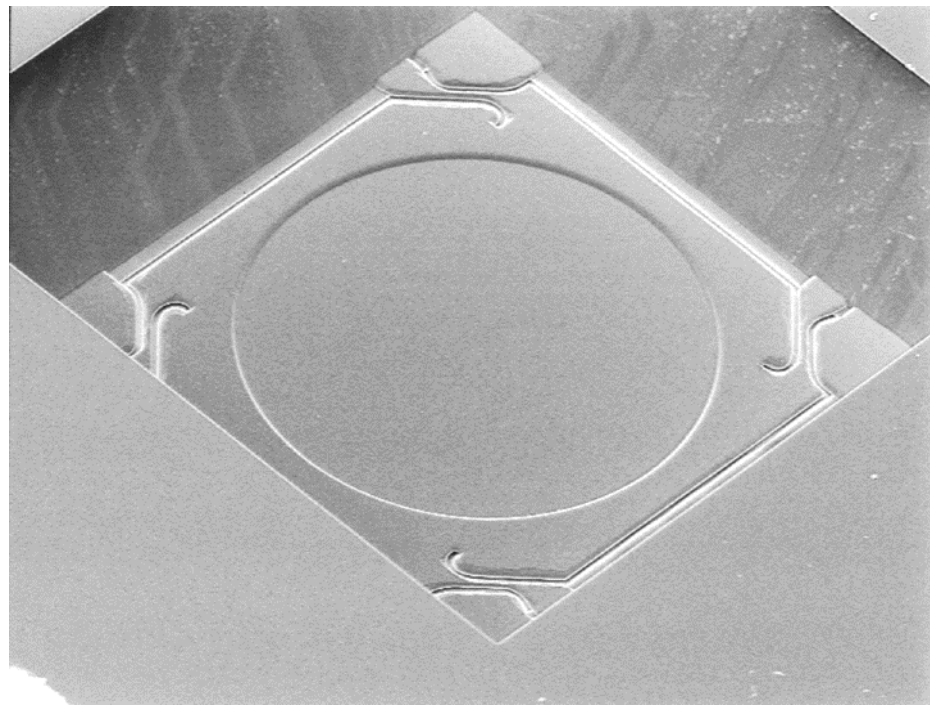
Micromachined Microphone With On-Chip Buffer Amplifier

Condenser Microphone 1mm Diaphragm



Top View:
Bridge Electrode and Electronics

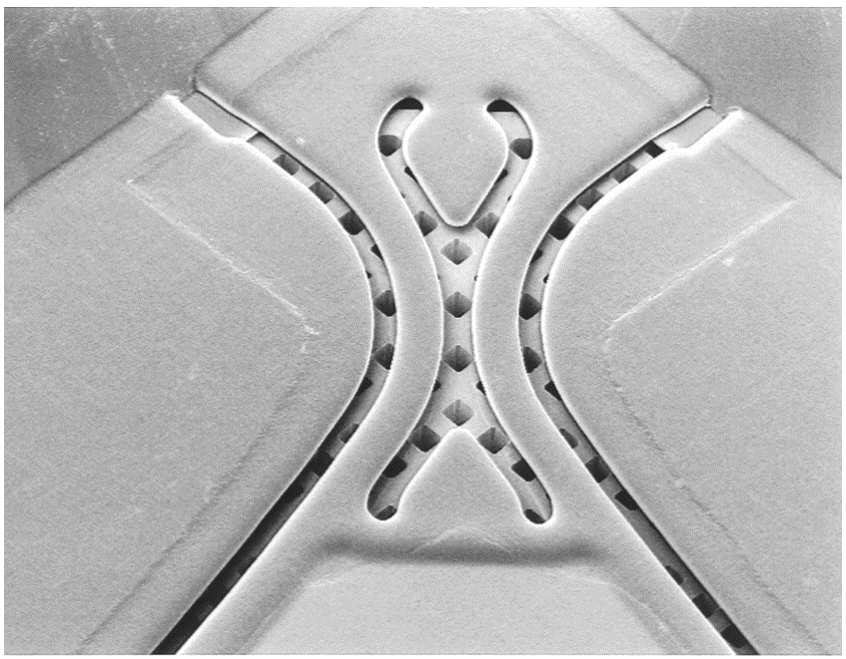
Bottom View of Diaphragm,
Etch Pit and Springs
Center of diaphragm is 1 micron thick,
Edges & springs are 6 microns thick

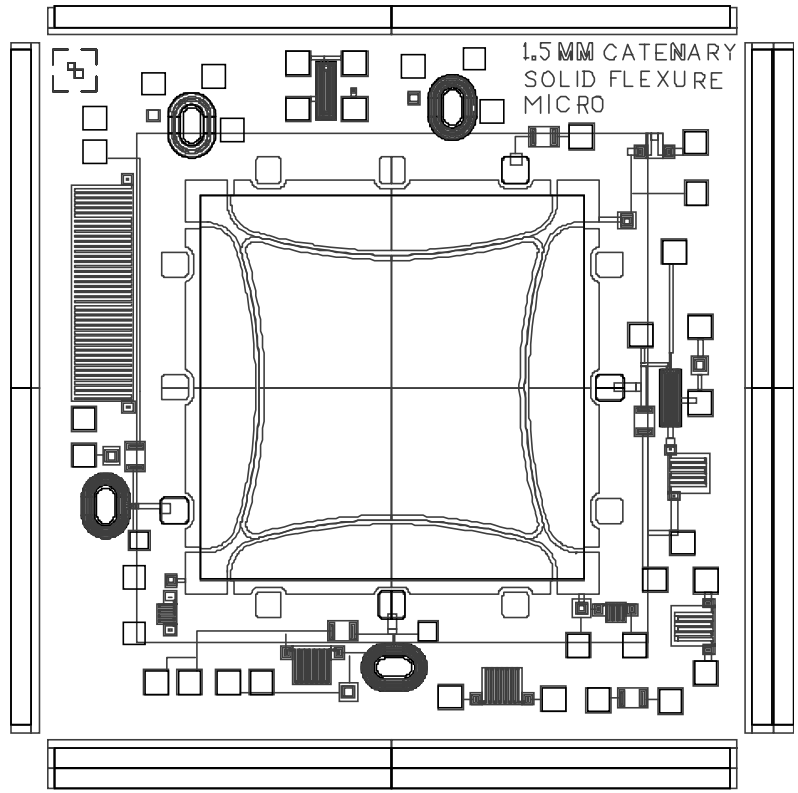


Micromachined Microphone with 1mm Diaphragm

Condenser Microphone Catenary Designs

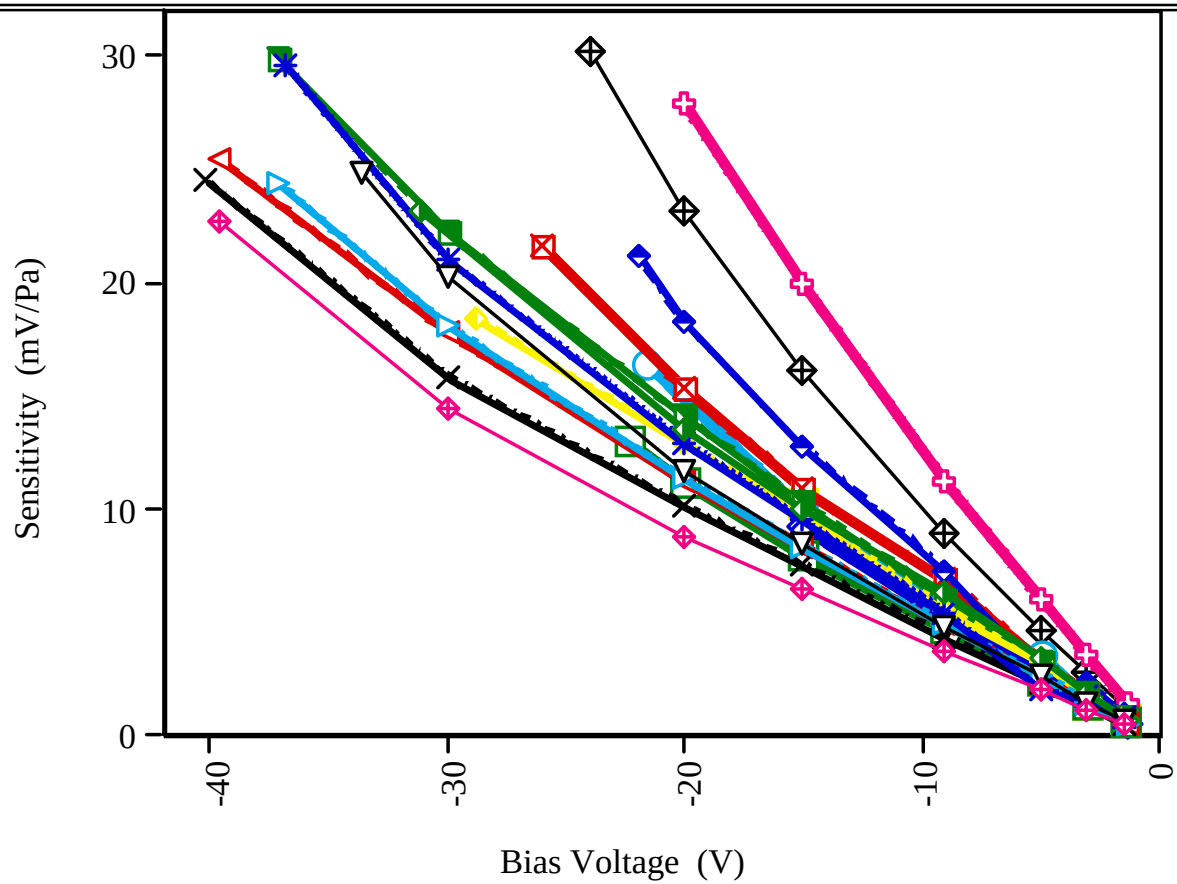
- To reduce mass of diaphragm, a 1 micron Si layer was used, with a thin border of 6 micron silicon for strength.
- Catenary shape gives good compliance & flatness
- LIGA-like 20 micron thick gold plated electrode





Mask layout drawing

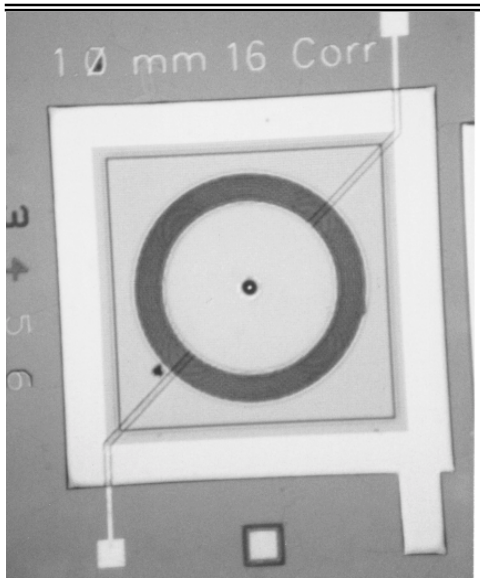
Condenser Microphone Sensitivity vs. Bias Voltage



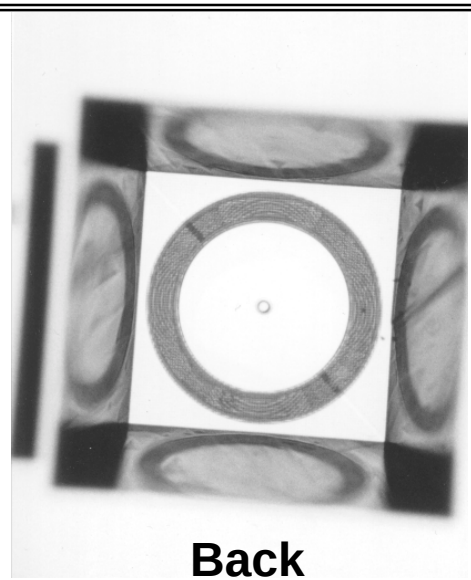
Sensitivity vs. bias voltage for various microphone designs

- Sensitivity & bandwidth of these miniature MEMS microphones are better than commercially available hearing aid microphones
- Bandwidth of 20-30 kHz depending on design

Nitride Membrane Microphones

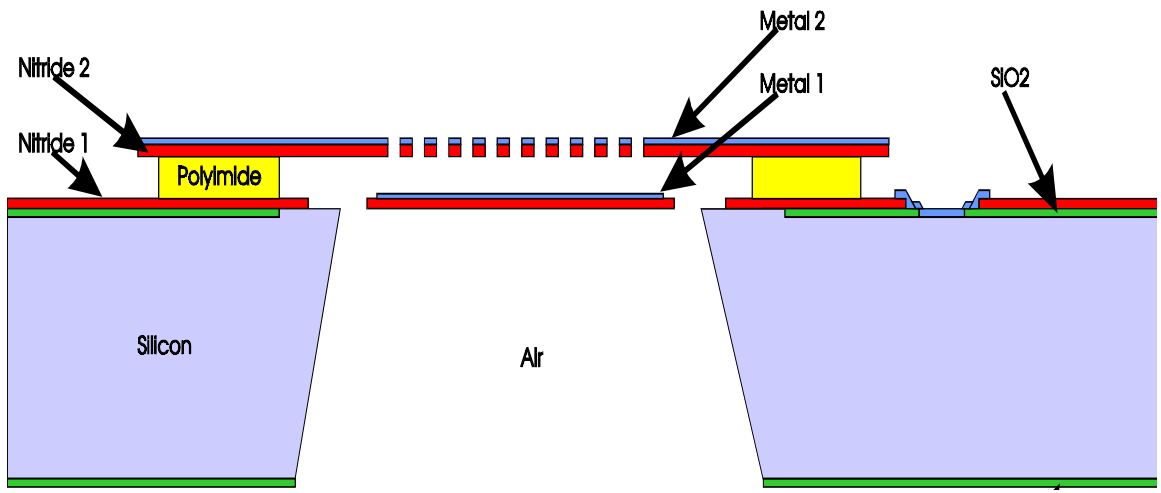


Round diaphragms with corrugations (front)



Back

- Silicon nitride membrane microphones were developed for increased bandwidth
- Novel fabrication process
- Polyimide sacrificial layer
- Stress-control of Si_3N_4 critical
- Work by B. Cunningham



Nitride diaphragm microphone cross-section

Conclusions

- **Draper has developed high sensitivity MEMS condenser microphones**
  - **On-chip JFET amplifiers to reduce stray capacitance**
  - **Single crystal silicon diaphragms**
  - **Electroplated perforated bridge electrodes**
  - **Si3N4 membrane fabrication process also developed**
- **Custom designs for ultrasound or infrasound possible**
- **Arrays can be built as easily as one sensor**
- **Technology licensed to:**

  NCT, National Semiconductor and Siemens (Munich)

References

- J.J. Bernstein and J. T. Borenstein, “A Micromachined Silicon Condenser Microphone With On-Chip Amplifier”, Digest of the 1996 Solid State Sensor and Actuator Workshop, pp. 239-243, Hilton Head, S.C., June 2-6, 1996.
- B. Cunningham and J. Bernstein, "Wide Bandwidth Silicon Nitride Membrane Microphones", SPIE Micromachining and Microfabrication Process Technology III, Austin TX, September 29-30 1997.